

INTEGRATED LAND USE/AIR QUALITY/WATER QUALITY CONTROL STUDY

Sonoma County, California

Contract No. 68-01-2648

Combined

INTERIM REPORT - October 10, 1975

and

MONTHLY PROGRESS REPORT - November 10, 1975

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I. INSTITUTIONAL/POLICY DIMENSIONS

A. Local Land Use Controls and Air and Water Quality

An initial review of the literature of the relationships between land use and air and water quality was undertaken as an integral component of the study effort. The intent of the review was to develop an understanding of the current research and analysis on the subject. The exploratory assessment helped to provide a theoretical basis for isolating issues and formulating Sonoma study hypotheses.

One of the first issues given consideration was the role of metropolitan size, form, and structure in determining ambient air and water quality. In analyzing the question, a number of reports were reviewed including a comprehensive study carried out by Brian Berry and colleagues at the University of Chicago,¹ and of other, more narrowly focussed, studies dealing with the air quality consequences of hypothetical urban forms.² Results of the review left³ many unanswered questions about the relationship of air and water quality to land use. Yet the exercise was useful in developing the broad outlines of the scenario generation and analysis process.

A key question raised was whether there is an optimum "urban form" for air and water quality or whether such quality results more from a complex and variable set of land use and transportation activities that take place with only a minimum relationship to urban form.

With that question in mind, the study moved from the "macro" "urban

form" level to the more "micro" level by making an assessment of land use controls that have a potential for achieving and maintaining desired air and water quality conditions. The December 1, 1974 Interim Report provides a list of the range of strategies considered. Much of the work was based on material contained in survey studies and EPA sponsored reports.

Now that a firm understanding of Sonoma County's development trends and the planning and development management process has been established, a second look has been taken at the detailed land use based air and water quality strategies. The intent has been to close the gap between planning theory and practice. The thrust of this effort has been to review the features included in the planning ordinances and development management procedures that can be strengthened or focussed to meet air and water quality objectives. Planning advisory⁴ publications were consulted, as well as the air quality plan for⁵ San Bernardino County which gives unusually explicit attention to the air quality aspects of various land uses. This review provided the background for analysis of Sonoma County plans and ordinances.

B. General Plans in California

Land use regulations, in the form of General Plans, or General Plan elements, zoning ordinances, subdivision ordinances, and grading ordinances, afford local governments in California with a broad variety of controls that are adaptable for air and water pollution regulation.

The California Planning and Zoning Law (Section 65000 of Title 7

of the Governmental Code) provides much of the basis for pollution control in California. Specifically, Chapter 3 details the framework for "Local Planning." It requires each county and city in the State to establish a planning agency whose functions include the development and maintenance of a general plan. This general plan is required to include the following elements:

- 1) land use
- 2) circulation
- 3) housing
- 4) conservation
- 5) noise
- 6) scenic highway
- 7) seismic
- 8) open space, and
- 9) safety.

Each of these elements requires a statement of development policies including objectives, principles, standards and plan proposals.

The Conservation Element is of particular importance to water pollution control.

(d) A conservation element for the conservation, development, and utilization of natural resources including water and its hydraulic force, forests, soils, rivers and other waters, harbors, fisheries, wildlife, minerals, and other natural resources. That portion of the conservation element including waters shall be developed in coordination with any countywide water agency and with all district and city agencies which have developed, served, controlled or conserved water for any purpose for the county or city for which the plan is prepared. The conservation element may also cover:

- (1) The reclamation of land and waters.
- (2) Flood control.
- (3) Prevention and control of the pollution of streams and other waters.
- (4) Regulation of the use of land in stream channels and other areas required for the accomplishment of the conservation plan.
- (5) Prevention, control, and correction of the erosion of soils, beaches, and shores.

Other general plan elements can also have significance to water pollution control. For example, the Open Space element lists the use of open space for the "protection of water quality and water reservoirs as well as for the protection and enhancement of air quality." The "Land Use Element" also has the potential of being related to water quality including the setting of building coverage to reduce water runoff.

No element is particularly adaptive to air pollution control. Because of this problem, the California legislature, in 1972 through Senate Bill 981, requested the development of guidelines for an air pollution control element in the general plans. However, the California Air Resources Board did not recommend such an element because: 1) the required environmental impact report on general plan elements would accomplish similar results, and 2) a local plan air pollution element could not resolve the problems of interregional transport of pollutants.

A planning consultant report, prepared as part of the SB 981 request, found similar problems with an air pollution element, including:

- 1) air quality modeling or forecasting could only be accomplished at an air basin level, and
- 2) interjurisdictional problems of plan development and enforcement would not be resolved.

Therefore, all efforts at creating a separate air pollution element in local general plans have been dropped. Theoretically, the

air quality consideration in general plans would come as a result of the environmental impact reports (EIR) on the other general plan elements. (To date, no EIRs for any General Plan and General Plan Element have been submitted in our study area.) In addition, total reliance on an EIR fails to recognize the need to adopt local government policies on methods of attaining air quality. Conceivably, such policies could be well addressed in the land use or transportation elements. However, since they are not specifically required, local planning agencies have generally not adopted specific air quality policies.

Enforcement of General Plans in California

The general plan has no direct legal effect. It must be implemented by various legal controls including zoning ordinances, subdivision ordinances, and a variety of other ordinances, regulations, and administrative rules. The general plan is also implemented by capital or operating budgets.

Zoning is the most frequently used general plan implementation tool. It can be particularly useful to air and water pollution issues because of their clear relationship to "public health, safety, and general welfare" of the police power.

California has taken a major step in tying the general plan policies to implementation by zoning in Section 65860 of the Governmental Code. This section aims at correcting the frequent misuse of zoning decisions that bear little relationship to the General Plan. (There is a similar requirement for subdivision ordinances.)

65860. (a) County or city zoning ordinances shall be consistent with the general plan of the county or city by July 1, 1973. A zoning ordinance shall be consistent with a city or county general plan only if:

- (i) The city or county has officially adopted such a plan, and
- (ii) The various land uses authorized by the ordinance are compatible with the objectives, policies, general land uses and programs specified in such a plan.

(b) Any resident or property owner within a city or a county, as the case may be, may bring an action in the superior court to enforce compliance with the provisions of subdivision (a). Any such action or proceedings shall be governed by Chapter 2 (commencing with Section 1084) of Title 1 of Part 3 of the Code of Civil Procedure. Any action or proceedings taken pursuant to the provisions of this subsection must be taken within six months of July 1, 1973, or within 90 days of the enactment of any new zoning ordinance or the amendment of any existing zoning ordinance as to said amendment or amendments.

(Amended by Stats. 1972, Ch. 1299. Effective December 22, 1972.)

65861. When there is no city planning commission, the legislative body of such city shall do all things required or authorized by this chapter of the city planning commission.

An interesting portion of this amendment is the enforcement of consistency through legal action by residents and property owners within the city or county.

Unfortunately, there has been no clear description of the word "consistent." A good discussion of this problem is presented in Land and the Environment: Planning in California Today. The report points out that no appellate court in California has been asked to clarify the matter. The Council of Intergovernmental Relations has provided some explanation.

"The Zoning Ordinance should be considered consistent with the general plan when the allowable uses and standards contained in the text of the Zoning Ordinance tend to further the policies and designated uses in the general plan and do not inhibit or obstruct the attainment of those articulated policies."

C. The Impact of New Forms of Zoning

A number of the recent zoning approaches in Sonoma, similar to the

rest of California and the United States, have shifted from a very rigid and patterned control to those with increasing administrative flexibility. Planned Unit Development zones, cluster zones, overlay zones, and performance standard zones have shifted the administration of zoning from rigid procedures to those with greater flexibility for reviewing environmentally or socially sensitive geographic areas. This new flexibility is particularly adaptive to the General Plan Policies in that the policies can be applied directly as part of mitigating conditions in the granting of zoning. The need for more complete data on a site can also be provided for by the Environmental Impact Reports (EIR) which are required in California on most zoning decisions.

For example, a particular parcel of land may not appear to be suitable for housing development from a water quality standpoint due to poor natural drainage conditions which could lead to rapid water runoff and greater stream pollution. Yet, an adopted general plan policy, included in the Conservation Element, might permit development in such areas when:

- 1) a detailed site investigation provided by an EIR indicates that structural means can be undertaken on the parcel to reduce the runoff problems, and
- 2) such structural measures (i.e., detention ponds, siltation basins) are included as part of zoning conditions.

The importance, then, of General Plans and Zoning Ordinances in California is that they provide the policy making and enforcement structure by which local level air and water quality land

use issues may be addressed. To summarize, the structure is:

- 1) the General Plans provide policy,
- 2) the zoning and subdivision ordinances must enforce the policies, and
- 3) EIRs provide the technical information by which flexible zoning decisions, based on both policy and site sensitive data, can be made.

D. Analysis of General Plan Policies for Air and Water Quality

A review was undertaken of all General Plans and Plan Elements in the study area for policy statements that are directly or indirectly related to air and water quality. Later, the policies were put in a matrix form as an aid to analysis and comparison.

The documents included:

Sonoma County

- o Statement of goals and policies of the draft General Plan (the statement is yet to be adopted but represents the present consensus of opinion)
- o Plans of unincorporated communities which vary in content from general to specific recommendations

Santa Rosa - General Plan and completed elements

Rohnert Park - General Plan and completed elements

Sonoma - General Plan and completed elements

Sebastopol - General Plan and completed elements

Healdsburg - General Plan and completed elements

Cotati - General Plan

1. Air Quality

Few of the plan documents reviewed give much explicit attention to air quality concerns. Only the County, Santa Rosa, Petaluma and Sebastopol make statements that can be interpreted as putting a major policy emphasis on preserving air quality. Some of the other plans make incidental policy recommendations that are specifically tied to reducing pollution or its nuisance effects, but do not make a general commitment to the maintenance or enhancement of overall air quality. All the plans include policy statements, which although not directly related to air quality concerns, are of potential relevance for improving air quality conditions.

Of all the planning documents reviewed, the Sonoma County goal and policy statement puts the strongest emphasis on air quality concerns. It includes a series of well articulated proposals directly addressing the question of air quality maintenance. Its suggestions include support for a land use pattern that minimizes the number of trips and vehicle miles travelled, promotion of a transportation system that reduces the number of air polluting vehicles, improvement of the efficiency of traffic control systems, regulation of point sources, control of indirect sources, and support of emission control device programs. Presumably, the County's soon to be completed air quality element will suggest specific measures to carry out each of the policy recommendations.

Some of the General Plan air quality policies of the various cities are quite general. Santa Rosa's Composite General Plan simply calls for the application of appropriate zoning standards to control

sources of pollution without further elaboration. Sebastopol's Open Space Element recommends cooperation "...with other public agencies in the development of agricultural, industrial, and transportation systems which will minimize air pollution and not result in economic hardship."

Air pollution caused by industries receives more specific attention in General Plan policies. Rohnert Park's plan calls for protecting residential areas from the air pollution and other nuisances associated with industrial uses. Healdsburg's plan also recommends reducing industrial/residential land use conflicts, and calls for a solution to the air pollution problems associated with sawdust burning at the sawmills.

Petaluma's planning documents indicate some degree of concern for air quality. The 1961 Petaluma General Plan recommended that heavy industries be located to the southeast so they would be downwind from the city. The city's more recently adopted Ecologic Resources Element, which is a combination of a number of the required Plan Elements calls for locally adopted performance standards for minimizing smoke, fumes, gases, dust, and particulate matter.

One unique feature of the Petaluma Ecologic Resources Element is the stress it puts on the role of reoxygenation in air quality maintenance. The policy calls for the preservation of water and vegetated areas, and the creation of planted buffer strips along major thoroughfares and around industrial areas for that purpose.

Policies aimed at reducing the dependence on the car through the arrangement of land uses can also be related to air quality. The City of Sonoma recommends that neighborhood convenience centers be allowed in order to reduce automobile use. Santa Rosa places a great deal of emphasis on creating a strong central activity center and providing housing in close proximity to it. The Windsor plan also calls for the concentration of employment and shopping activities and balancing housing with employment. The plan for the Sonoma State University environs includes a variety of policies that emphasize the creation of a high density, pedestrian-oriented community around the new Sonoma State campus.

Although only the County explicitly relates its policies for transportation to the maintenance of air quality, most of the other planning jurisdictions also make recommendations in these areas that could contribute to the achievement of air quality goals. Both Petaluma and Santa Rosa suggest the expansion and improvement of local bus systems. Rohnert Park and the Windsor area plan recommend that access to arterial streets be controlled in order to improve traffic flow. Virtually all the plans call for the creation of networks of pedestrian ways and bicycle paths.

2. Water Quality

On the whole, water quality-related factors receive more attention in the local general plans than do air quality considerations. There is more emphasis on acceptable water quality as a generalized goal and as an effect of specific policies. Additionally, the plans recommend a variety of measures that could potentially support

water quality maintenance and improvement without explicitly linking the actions to water quality goals. The County and virtually all the cities identified the preservation of water quality as a general goal to be achieved. The County, Santa Rosa and Petaluma tie the general goal of preserving water quality to the more specific objective of protecting aquatic life in local waterways.

Petaluma, Rohnert Park, Sebastopol and Healdsburg, which are wholly or partially dependent on local wells and reservoirs for their municipal water supplies, stress the need to maintain water quality in order to protect their municipal sources. Petaluma recommends that the land surrounding its reservoirs be kept in open uses and managed to prevent erosion and pollution. In order to do this, the use of easements, and land use control measures to prevent urbanization are suggested. Additionally, management techniques to regulate grazing and control drainage are recommended. Because the watershed lands are beyond the city's own jurisdiction, it is further recommended that all governmental actions affecting the watershed area be carefully evaluated for their impacts. Sebastopol proposes that the area surrounding it be zoned for large agricultural parcels in order to protect ground water quality and to ensure recharge. Healdsburg also proposes limiting urbanization on recharge areas. It further suggests that when development does take place, sufficient open space be left to allow for ground water recharge. The County calls for protection of ground water and of recharge areas, but the specific means of doing so have not yet been spelled out.

Although none of the plans for unincorporated areas mention the preservation of water quality as a general goal, they do pay attention to the problems of failing septic tanks and the need to protect the ground water sources of domestic and agricultural water supply. In semi-urbanized areas with concentrations of failing septic tanks, the plans recommend the expansion of community sewage collection and treatment systems. Many of the plans propose that proof of adequate percolation be required as a condition of new rural lots.

Few of the plans reviewed considered the management of natural resources and resource extraction as a factor in water quality maintenance. Only the County, Petaluma and Healdsburg specifically recommend forbidding disposal of wastes in streams, floodplains or other areas where water contamination might occur. The County suggests that measures be taken to regulate forestry, agriculture, and mineral extraction to reduce erosion and protect water quality. The plans for unincorporated areas in forested portions of the County recommend regulation of forestry to prevent land instability and erosion. The Forestville area plan proposes that the timing of fertilization be controlled to protect water quality, and the Petaluma plan recommends that the use of pesticides be limited.

Although the increased runoff and soil erosion that often accompany land conversion and development affect water quality, these problems receive no attention in most of the plans. When they are considered, it is often in a somewhat limited way. Santa Rosa, for example, simply calls for the preservation of natural vegetation. The Forestville area plan calls for replanting, and vegetation

preservation. Sebastopol goes further by encouraging replanting, grading plans for all projects, and design and development management techniques to minimize soil erosion. Petaluma's Ecologic Resources Element is the only plan with a fairly complete set of recommendations in this area. Besides suggesting all of the measures already mentioned, it recommends that the grading ordinance be kept current, that development be regulated to reduce runoff, and that projects that would produce excessive erosion be forbidden.

The plans devote little attention to the potential role of site design factors in contributing to improved water quality. Only the County and Healdsburg call for site plans that minimize runoff. Only the County and the Forestville area plan specifically mention the provision of on-site drainage improvements, although the Windsor plan does recommend on-site ponding of runoff in cases where a development would create major increases. The County and Rohnert Park suggest reducing requirements for pavement widths in residential areas, although the intent is to improve the aesthetics, rather than reduce runoff. Many of the plans recommend planned unit development concepts to allow clustering and the preservation of open space, but the water quality benefits are seldom mentioned.

Somewhat more attention is paid to the special problems associated with hillside development, and the implications for erosion and water quality are occasionally cited. The Petaluma and Sebastopol plans, as well as virtually all the plans for the unincorporated areas, call for large lots or otherwise reduced densities in the hillside areas. Santa Rosa, Petaluma, Sebastopol and a few of

the unincorporated areas recommend no development at all in areas of especially unstable slopes. These plans also suggest preservation of natural vegetation and processes. Only Petaluma, Sebastopol and Healdsburg suggest that street improvement requirements be modified to reduce cuts and fills. Sebastopol's plan is the only one that makes specific site engineering suggestions by recommending that energy dissipators be required to reduce erosion.

Virtually all of the plans reviewed devote a great deal of attention to the preservation of natural stream channels. In only a few cases is water quality protection mentioned as an objective. Generally, the intent seems to be to preserve the aesthetic qualities of the stream side vegetation. Most of the plans recommend building set back and floodplain regulations to achieve their objectives. Only Petaluma and Santa Rosa go so far as to suggest the purchase of land or easements along the streams.

3. Evaluation of General Plan Air and Water Quality Policies

Given the newness of the idea that local planning and land use control authority can be applied to the solution of air and water quality problems, and the lack of detailed direction in this area in the state's local planning law, it is no surprise that the plans reviewed tend to be deficient in their treatment of air and water quality issues.

Most of the plans considered here treat air and water quality concerns tangentially, if at all. In few cases do the plans discuss the nature of the local meteorological and hydrological systems,

levels and sources of air and water degradation, implications of air and water quality conditions for the community, or the rationale for taking steps to maintain air and water quality. Because the dimensions of the air and water concerns are not treated in a systematic way, the goals and policies that are suggested tend to be hit or miss and provide no basis for determining if they present a coherent program.

A related problem is that since the specifics of local air and water quality issues are not identified, there is no framework for evaluating the appropriateness of any goals and policies that might be recommended. For example, the plans do not provide enough information to determine whether or not the preservation of streamside vegetation is especially critical for the maintenance of water quality or if other measures would deserve a higher priority.

When the plans did set goals for air and water quality they were most often stated in vague terms such as "maintain air quality" or "preserve the quality of surface and groundwater." In only a few cases is there an attempt to make the goals specific by relating them to tangible objectives such as preserving aquatic life, or reducing view-obscuring smog. Even these attempts fail to go far enough, because they do not provide the qualitative or quantitative standards necessary to guide policy selection or measure goal achievement.

In most cases the air goals are not supported by well-defined policies to effect their achievement. Most of the policies that

are suggested are as vague as the goals, seldom spelling out the specific public actions or changes in procedures, administrative guidelines and regulatory ordinances that might be required.

II. DEVELOPMENT OF ALTERNATIVE LAND USE CONFIGURATIONS

A. Economic Assumptions

A series of assumptions/policies have been developed for commercial/industrial land use and employment growth in the various scenarios. These assumptions parallel those created for residential growth.

The end products of this effort were: 1) number of employees per commercial or industrial land use per city, and 2) number of acres per commercial or industrial land use per city. These computations were then adjusted for each scenario to fit the basic approaches of the residential assumptions and to test the effect on air and water quality of various patterns of employment distribution.

The steps taken to establish the future employment and land use estimates were:

- 1) Project future economic trends and their related effects on employment .
- 2) forecast employment in Sonoma by major employment/land use categories that were grouped specifically to assist water quality modeling
- 3) establish floor space and land absorption factors by each land use (and per city if necessary) to determine commercial/industrial acreages required per scenario
- 4) develop a set of assumptions by each scenario for the distribution of the various employment categories both within Sonoma County and within the cities.

B. Projection of Future Economic Trends and Employment Patterns

Sonoma County Planning Department, as part of their General Plan preparation, contracted with University Research Center (URC) affiliated with Sonoma State University to project employment in the County for the 478,000 and 630,000 residential population estimates of the Continuing Trends scenario. This document has provided the basic employment data for the other scenarios.

To supplement the URC report, additional forecasting was conducted by ABAG using a different method. The relationship of county and city size to such variables as housing units (single family and multi-unit) employed residents, non-family residents (e.g., single persons) and employment (basic and local serving) was analyzed at a San Francisco-Oakland and San Jose SMSA level. Regression analysis, using 1970 census data, was used to establish the relationship of:

- 1) persons in the labor force to resident population
- 2) employment to employed residents
- 3) basic to local serving employment
- 4) single family housing units to all housing units

This ABAG analysis had some minor differences with the URC report. These differences were created because URC basically used current trends in Sonoma County as a projection device while ABAG used a comparative method to other cities within the ABAG region to develop its projection formulas. However, since some of the employment factors could be reflected in different car/trip making patterns and therefore affect the validity of the car emission regression formula (to be discussed later) it was decided to accept

without modification the URC employment figures.

An important part of both forecasts was an interview with the County Economic Development Agency to verify if some of the employment projections could be justified. Recent and anticipated employment activities were reviewed.

C. Employment Forecast by Land Use

The following employment categories were used:

A. Basic employment groups

1. Agriculture, forestry, fisheries and mining. (AGM) (1, 2)
2. Industrial - includes manufacturing, long distance transportation and wholesale trade. (IND) (3-9)
3. Office - includes insurance carriers, holding companies, business services, large federal and state installations. (OFF) (9-12)

B. Local serving employment groups

1. Retail, services and offices - includes retail trade and services, local finance, insurance and real estate and local government. (RSO)
2. Construction, transportation, communication and utilities. (CTCU) (13, 14)

The above 5 group system is based on the 18 group system used in County Employment Projections (ABAG/MTC/DOH, County Employment Projections, January 1973). Acronyms shown above are for the purposes of the Sonoma Study. The numbers shown after the acronyms correspond to the industry groups in County Employment Projections.

The land use categories were selected because they readily fit water quality modeling.

D. Floor Space and Land Absorption Factors

The floor space and land absorption factors for the study were derived from:

- 1) 1970 Federal Highway Administration report - Edward A. Ide, Estimating Land and Floor Area Implicit in Employment Projections (Federal Highway Administration, July 1970), Table 2.1, pp. II-13 to II-17.
- 2) composite of densities for the 2 digit SIC groups weighted by Sonoma County's August 1972 industry structure, and
- 3) analysis of Sonoma County May 1971 land use inventory.

Some variance was necessary for the different cities in Sonoma County due to the existing and future pressures for building intensity. The factors are given below.

E. Assumptions for Employment Growth in Study Scenarios

The assumptions for the distribution of commercial/industrial employment and land use distribution are listed below. Those for Continuing Trends have yet to be set.

Santa Rosa Centered and Urban Centered Scenarios

1. Follow the employment distribution pattern established in the Sonoma County/URS forecasts.
2. Locate basic industrial development at 20 employees per acre and local serving construction/transportation at 12 em-

- employees per acre in the center of the city working outwards.
3. Locate all basic offices in the center using 145 emp./acre.
 4. Local Serving - Retail, Service, Office

Santa Rosa:

50% in center using up to 60 employees/acre

50% in suburbs using up to 18 employees/acre

Petaluma:

Same as Santa Rosa

All other cities:

50% in center at 18 employees/acre

50% in suburbs at 18 employees/acre

Suburban Dispersed and Rural Dispersed Scenarios

1. Locate basic industrial development at 20 employees and local serving construction/transportation at 12 employees per acre starting at the outside and working into the center.
2. Locate 50% of the basic office in the center at 145 emps./acre and 50% of the basic office in the suburbs at 72.6 emps./acre
3. Local Serving - Retail, Service, Office

Santa Rosa and Petaluma:

Locate 75% in the suburbs at 18 employees/acre

Locate 25% in the center at up to 60 employees/acre

All Other Cities:

Locate 25% in the center at 18 employees/acre

Locate 75% in the suburbs at 18 employees/acre

III. AIR AND WATER QUALITY ANALYSIS

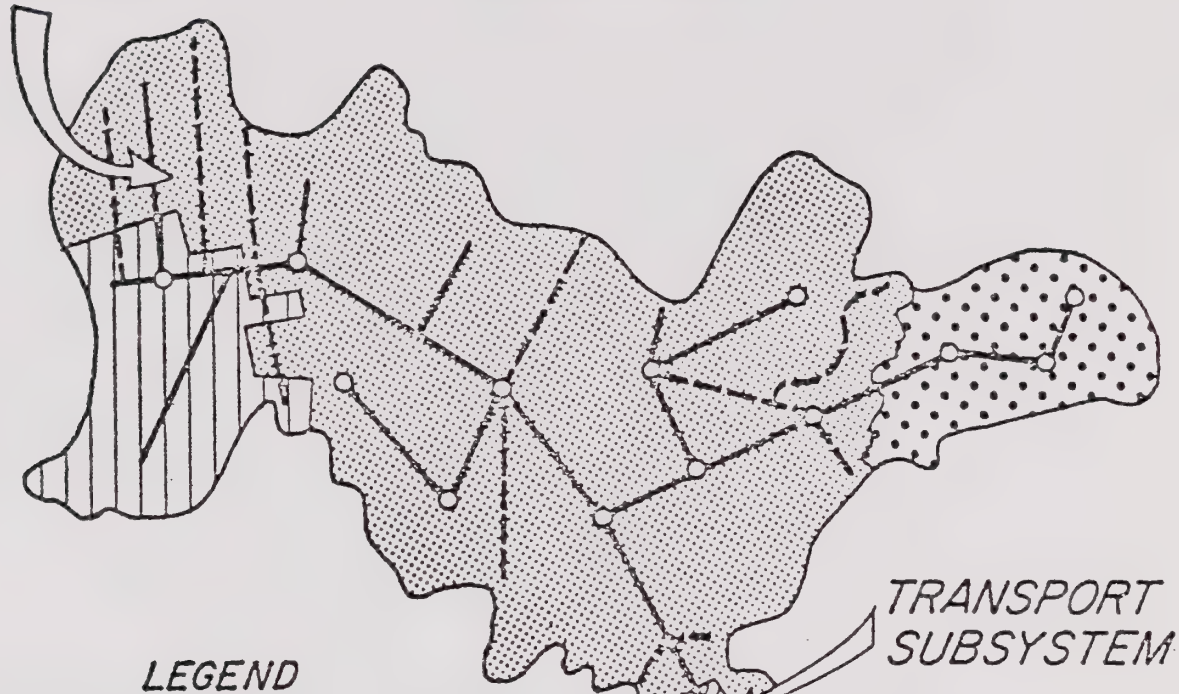
A. Water Quality Analysis

Progress in water quality analysis has been substantial since the execution of the contract between ABAG and Water Resources Engineers (WRE). Considerable effort has been devoted to determining the watersheds and subareas and the representation of these areas using the ABAG scenario land use system. Extensive field data have been collected regarding stream and channel parameters, and modifications are being made to the water quality models to adapt them to the needs of the Sonoma Study.



The water quality model which will be employed by WRE to determine the implication of different scenarios is a combined version of the Urban Storm Drainage Model (Figure I) and the Agricultural Run-off Model. Both of these are modifications of the EPA Stormwater Management Model (SWMM), but they route runoff from each watershed sub-area into a single drainage channel rather than directly routing runoff into discrete gutters or sewer inlets.

The modeling system is in two parts - a surface runoff model (Figure II) and a stream quality model. The latter, QUAL-II, has been discussed in previous reports. The surface runoff model computes the changing quantity and quality of overland flows coming from the impervious and pervious surfaces of the individual watershed subareas and routes them to the major drainage channels of the sub-area. Application of the surface runoff model is based upon decomposition of the total watershed into subcatchments which are relatively homogeneous with respect to land use and hydraulic properties.

SURFACE RUNOFF SUBSYSTEM



LEGEND

-  *Land Use A*
-  *Land Use B*
-  *Land Use C*

TRANSPORT SUBSYSTEM

interceptor

outfall

RECEIVING WATER SUBSYSTEM

FIGURE 1

THE URBAN DRAINAGE SYSTEM

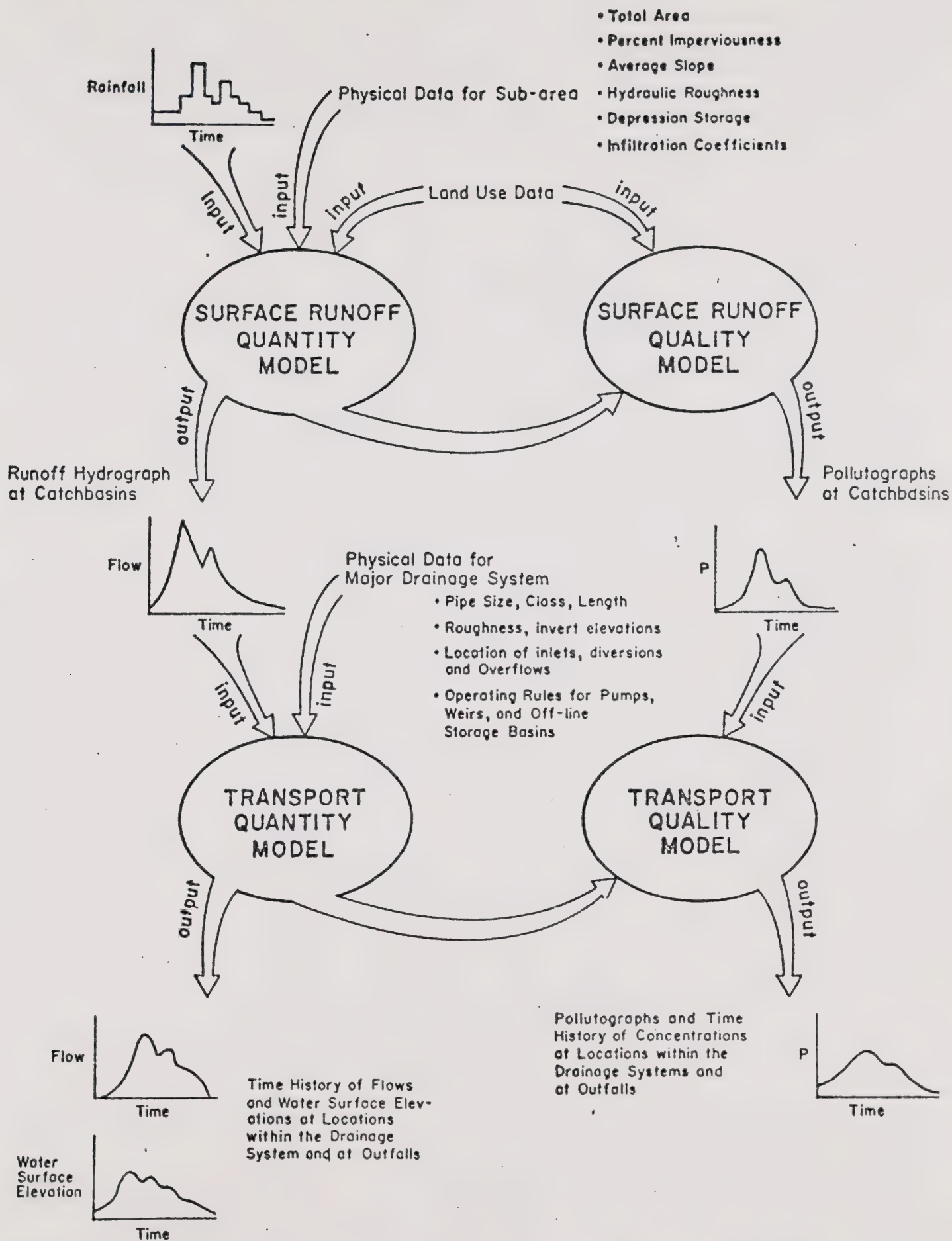


FIGURE 2
STRUCTURE OF SURFACE RUNOFF AND TRANSPORT MODELS

The land use and degree of impervious surface are two principal parameters determining the quantity and quality of surface runoff. The other input data are average slope, hydraulic roughness, infiltration coefficients, and detention storage.

To compute the runoff hydrograph from each subarea, flow routing upon plane surfaces is performed on the rainfall excess, determined as input rainfall minus infiltration and detention storage. The surface runoff from the subarea then forms a runoff hydrograph for each collection point and becomes an input to the surface water model. The quality of the surface runoff is computed by an empirical method that exponentially decays over time the amount of dust and dirt on the subarea with the rate coefficient that is proportional to the rate of runoff. Appropriate coefficient and pollutant loadings are calculated for each land use type. The surface runoff is then routed to give pollutographs, i.e., the mass emission rate (kg/sec) of various pollutants over time during the storm period. The quality contributions from the subareas are routed to the surface waters, where stream modeling is used to compute the time varying quality of the surface waters.

1. Work Schedule for Water Quality Model

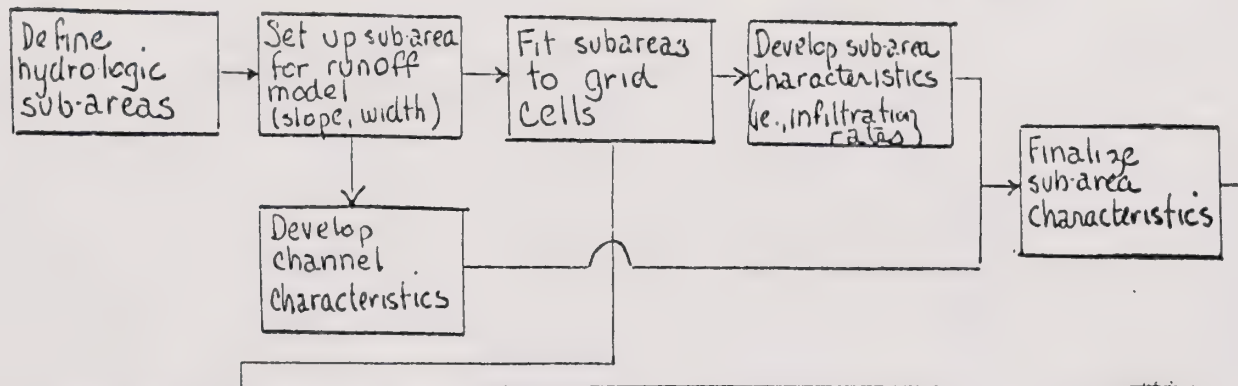
Figure III provides a work flow chart on the water quality modeling effort. It includes the major elements of:

- 1) defining the hydrologic sub-area characteristics (which will be explained later in the report),
- 2) adapting the runoff and QUAL II models to Sonoma County,
- 3) preparing land use data (as explained in previous Progress

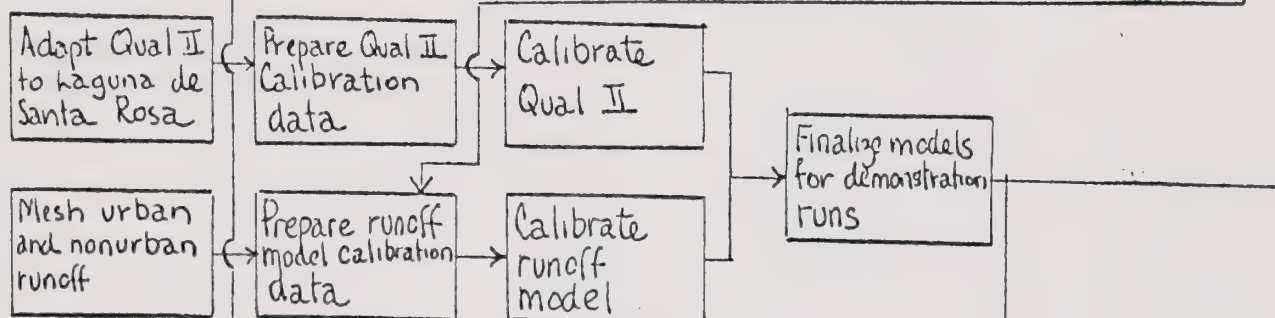
FIGURE III.

Water Quality Work Flow

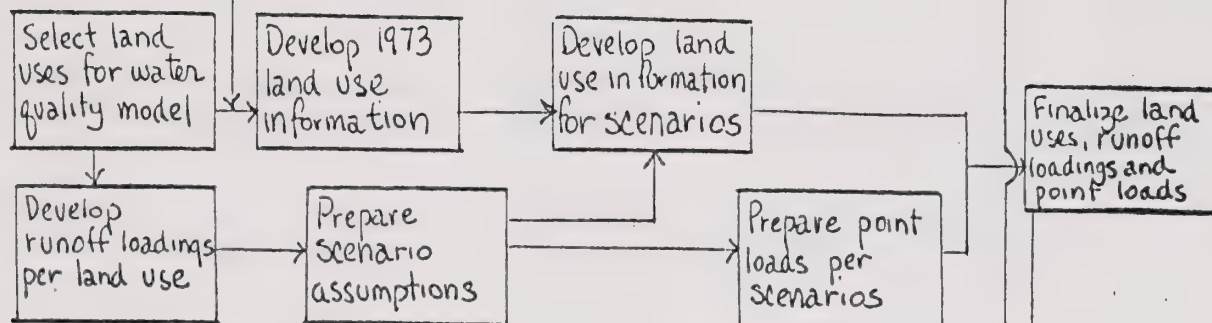
Define Hydrologic Subareas Characteristics



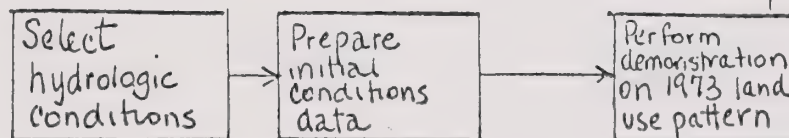
Adapt Runoff & Qual. II Models to Sonoma County



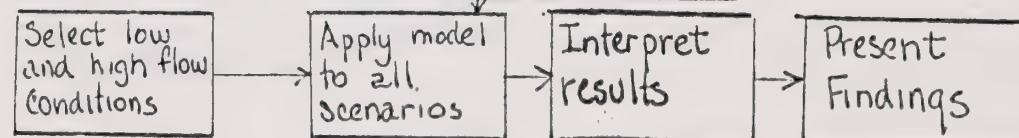
Prepare Land Use Data



Conduct Model Demonstrations



Assess Land Use Impacts on Water Quality



Reports),

- 4) demonstrating the model to test its use on the various input items, and
- 5) assessing the model output in terms of both the impact of land use patterns on water quality and its relationship to air quality information and analysis.

2. Definition of Sub-Area and Channel Characteristics

Having defined the two major basins in the study area, Laguna de Santa Rosa and Petaluma River, the next step was to develop runoff characteristics for the sub-areas and hydraulic properties of channels draining the sub-areas. The sub-areas are represented in the model as idealized rectangular areas having uniform groundcover and slope. However, because real catchment areas do not experience uniform overland flow, average values must be assigned to each sub-area.

Actual channel site examinations were necessary in order to determine the specific characteristics of channels represented in the model. Sixty-one stations were chosen for observation in the Laguna Basin. (Representative stations in the Petaluma Basin will be determined at a later date.) Each station provided a representative cross-sectional area at a portion of a channel. Stations were located at the headwaters, near the middle of the channel, and at downstream locations. Accessibility from a road was also a locational factor. This facilitated quick egress when being pursued by irate property owners.

Data collected at each station included channel width, depth of

water and slope of the channel banks. Special note was taken of the roughness condition of the channel. A Manning coefficient was specified based on observations made at each station.

These data will be incorporated in the model to represent the sub-areas and channels draining the sub-areas. The model will simulate hydrographs for various storm events for the sub-areas.

3. Definition of Hydrologic Sub-Basins

As discussed in previous Progress Reports, two major basins were chosen to be modeled for water quality--the Laguna de Santa Rosa and the Petaluma River Basin.

To avoid confusion, the watersheds of the main stems (the Laguna and Petaluma River) were termed "basins" and the watersheds of the major tributaries were termed "watersheds." These watersheds were, in turn, broken down into smaller hydrologic units called "sub-areas."

Sub-areas were defined using the following criteria:

- 1) areas of homogeneous slope,
- 2) areas of homogeneous land use, and
- 3) overland flow path lengths from points along the perimeter of a sub-area to the tributary draining the sub-area were roughly comparable.

Each sub-area contained one or more tributaries or parts of tributaries. In the cases where more than one tributary drained a

sub-area, a single tributary was chosen, for modeling purposes, to represent the main drainage channel from that hydrologic sub-unit.

The steps taken to divide the study area in these hydrologic boundaries on 1:24,000 scale topographic maps were:

- 1) delineation of the "basin" boundaries of the Laguna de Santa Rose (Laguna) and Petaluma River,
- 2) definition of the major tributaries of these rivers and their "watersheds." In the case of the Laguna, they were: 1) Windsor Creek, 2) Mark West Creek, 3) Santa Rosa Creek, and 4) Upper Laguna (Copeland Creek), and
- 3) delineation of the sub-areas. The Laguna Basin was subdivided into a total of 40 sub-areas. No major tributaries were defined in the Petaluma River Basin because of its relatively small size. Consequently, there is only one watershed. 15 sub-areas were delineated in the Petaluma River Basin.

After all the watersheds and sub-areas were defined in both basins, their hydrologic boundary lines were translated into 1-km grid cell lines. Thus all sub-areas were described in terms of grid cells, making them compatible with the scenario land use data system. The size of sub-areas was large enough to allow for reasonably accurate representation as aggregations of grid cells. The smallest sub-areas contained 7 grid cells and the largest contained 42.

4. Determining the Impervious Surface Standards

The land use categories used in the employment forecasts were

first determined for their appropriateness to the water quality modeling efforts. For example, certain employment, and their related land use categories, were identified as being more probable of being decentralized in suburban settings with an anticipated lower percentage of impervious surface than the same use in a "downtown" location.

Table I provides the recommended percent impervious standards. They are presently being reviewed for a further refinement based on actual measurement in Sonoma County.

The methods used in determining these preliminary impervious percentages were:

- 1) review of existing zoning codes in Sonoma County for lot coverage requirements
- 2) application of professional experience by our water quality consultants, WRE, from researching similar areas, and
- 3) review of literature on impervious surface.

A review of aerial photo maps of Sonoma County will be undertaken to establish existing impervious surface percentages. Different land uses and densities will be analyzed. This will enable further refinement of the standards.

New ordinances aimed at reducing runoff are also being considered in the runoff forecasting. Such runoff controls can include on-site detention requirements such as in Albuquerque, New Mexico; Bellevue, Washington; and Boulder, Colorado. Similarly, performance

TABLE I. PRELIMINARY RECOMMENDED PERCENT IMPERVIOUS
SONOMA COUNTY STUDY AREA

Percent Impervious	Base Year Land Use	Alpha Code	Scenario Land Use
10-40	Single Family	RL	Residential-Low Density 5 du (1-9)
60-70	Multi-Dwelling	RM	Residential-Med. Density 15 du (10-19)
70-80		RH	Residential-High Density 32 du (20+)
95	Commercial	CC	Commercial (Retail/Office) City Centered*
90		CS	Commercial (Retail/Office) Suburban*
98	Industrial (Includes Industry, non-urban Industry, trans., and sand)	IC	Industrial - City Centered*
95		IS	Industrial - Suburban*
6	Grazing and Open Space	G	Open Grazing
6	Agricultural - Orchard/Vineyard	AV	Vineyard/Orchard
6	Agricultural - Truck/Field Crops	AF	Agricultural - Truck and Field Crops
100	Wetlands	W	Wetlands
90	Freeways, Airports, Railyards	-	--

*The "Centered" versus "Suburban" distinction relates more to the potential for larger amounts of impervious surface rather than their geographic location.

zoning techniques that emphasize reduced percent impervious surfaces, such as found in Bucks County, Pennsylvania, will be considered in adjusting the impervious surface factor that is used in the runoff forecasts.

B. Air Quality

1. Emissions Factors

Between the time of the air quality analysis of the Baseyear (1973) and the Baseline (2000 - Continuing Trends) and the air quality analysis for the scenarios, EPA published Supplement Five of its Air Pollution Emissions Factors Handbook (AP 42). This publication contains revised vehicular emission factors and the question was raised whether the Sonoma Study should use these factors. The previous emission factors were those of the BAAPCD as modifications of Supplement Two. A meeting was held between EPA, BAAPCD, ABAG, and URS representatives to discuss the issue.

The reasons for using these Supplement Five factors were:

- a. Supplement Five factors are more accurate than Supplement Two. The current district factors, which have been used in the completed analysis runs, are modifications of Supplement Two.
- b. The study might be faulted for not using the most current data which was released in April, 1975. (The air quality analysis was started in November, 1974.)

The reasons for continued use of the Supplement Two factors are:

- a. Several items of interest have been omitted from consideration in the study (modal split ratios, downtown pedestrian malls)

in order to ensure consistency among scenarios. Using different emission factors for certain scenarios would confuse the comparison of the land use variation.

- b. Difficulty in applying Supplement Five factors. The data presentation in Supplement Five is no longer in a simple tabular form.

The possibility of rerunning the first analysis with the Supplement Five factors was also discussed, but was determined as inappropriate due to the approximately \$1,000 cost per run for all four pollutants.

The BAAPCD presented a chart of their preliminary emission factors based upon Supplement Five. A comparison of the two sets of emissions showed:

- a. CO - not much difference (10%).
- b. Particulate - 50% increase due to tire wear. However, the particulate background factor is likely to decrease the effect of this difference.
- c. HC - geographic distribution possibly not so important since rollback will be the main oxidant analysis method.

As a result of the discussion, it was decided to remain with the current BAAPCD factors (Supplement Two as modified) to ensure consistency among the scenarios.

Oxidant Analysis

At the meeting mentioned above, oxidant analysis for the study was discussed. Two photochemical models were mentioned. DIFKIN is

currently being used by the Metropolitan Transportation Commission (MTC) to evaluate the ABAG regional projections. This work will provide an evaluation of oxidant levels in southern Sonoma County created by emissions from other parts of the ABAG region as conditioned by different wind patterns. It is not currently set up to analyze the entire County or to determine oxidant concentrations within the County due to internal emissions. The LIRAQ model, developed by the BAAPCD and the Lawrence Livermore Laboratory, will need to be calibrated before it can be used. The emissions inventory will also need modification, and it is questionable whether one run of this model will be possible for our study.

Rollback was then discussed as the only method of oxidant prediction. Several points were made for alternative analysis to supplement the standard rollback technique:

- a. use a three year average to determine the rollback high oxidant value rather than the highest value,
- b. analyze the Santa Rosa plain separately, as it is topographically separated from the Petaluma plain,
- c. consider the current oxidant values as background and use rollback on the incremental values. This approach would reflect the possibility that the current oxidant levels are externally caused.

The possibility of analyzing the HC/NO ratio was also brought up.

2. Vehicle Kilometers Travelled (VKT) Estimation

Statistical regression analysis is being used to derive gridded vehicle emissions for the alternative land use scenarios. The

process has been described in earlier progress reports and the analysis is near completion.

The various independent variables in the regression were specified for different geographical areas as established in the procedures for developing the scenarios. Population is given by grid cell, but employment is predicted only at the census tract level. Since the dependent (predicted) variable is emissions per grid cell, it was suspected that the census tract employment figures might not provide sufficient information to be significant. This proved to be correct.

The variables that will be tested were the functions:

$$f_c = \sum_i \frac{(\text{city pop})_i}{(\text{dist})_i}$$

$$f_l = \sum_j \frac{(\text{loading of major link})_j}{(\text{dist})_j}$$

These functions are measures of proximity to major traffic arteries and cities. Specifically, f_c for a grid square is the population of each city divided by the distance from the grid square to the city, summed over the six cities in the study area. f_l is similarly defined - the average daily traffic (ADT) of each major traffic artery of greater than 10,000 ADT in 1973 in the study area, divided by the distance from the grid square to the artery, summed over all the major arteries. In addition, different forms of the denominator were investigated (e.g., $f'_c = \sum_i \frac{(\text{pop})_i}{d_i^2}$).

Results so far show that approximately 50% of the variation between cells of carbon monoxide and particulate vehicular emission can be

explained by a combination of cell population, f_c and f_ℓ . The regression equation for CO is

$$\begin{aligned} \text{CO}_{\text{cell}} \text{ (kg/day)} &= (.02441) \text{pop}_{\text{cell}} \\ &\times (.1125) f_\ell \\ &\times (.003071) f_c \\ &- 24.256 \end{aligned}$$

The employment distribution is reflected in f_ℓ , since traffic loadings depend on employment and residential distribution.

Problems and Limitations

Work will proceed in refining the coefficients in the regression equation. Particularly the predicted emissions patterns have yet to adequately reflect the hot spots. They tend to smooth out the variations in emissions between grid cells. A further limitation of the regression analysis is that it forces some consistency between Baseyear and Baseline data and that of other scenarios on some factors where consistency may not be desirable. The underlying basis of the regression equation is VKT between various land uses and VKT is estimated based on assumed trip patterns by the population. Therefore, any major alteration to the basic trip patterns per population could affect the VKT between land uses and have a related effect on the regression equation. Such employment and population elements that required consistency were percentage of employed people in the total population or the number of outcommuters. Therefore the use of the regression equation restricted the types of alterations that could be made in the scenarios.

1. Brian J. L. Berry, et al., Land Use, Urban Form and Environmental Quality (Chicago: University of Chicago, 1974)
2. Among the studies whose findings were considered were:

Alan M. Voorhees and Associates and Ryckman, Edgerly, and Tomlinson and Associates, A Guide for Reducing Air Pollution Through Urban Planning prepared for the Office of Air Programs, U.S.E.P.A., 1971;

J. A. Kurtzweg and D. W. Weiz, Determining Air Pollution Emissions from Transportation Systems, National Air Pollution Control Administration;

TRW, Inc., Air Quality Management Plan and Program Recommendations Middlesex County, New Jersey McLean, Va.: TRW, Inc., 1974;

B. H. Willis, J. R. Mahoney, and J. C. Goodrich, The Hackensack Meadowlands Air Pollution Study; Task 4 Report: Air Quality Impact of Land Use Planning Lexington, Mass.: Environmental Research and Technology, Inc., 1973.
3. "The Relationship of Land Use and Urban Form to the Achievement of Ambient Environmental Objectives: Some Preliminary Considerations and Selected Bibliography," unpublished research paper, Association of Bay Area Governments, April., 1975.
4. Charles Thurow, William Taber and Duncan Erley, Performance Controls for Sensitive Lands: A Practical Guide for Local Administrators (Washington: U.S.E.P.A., March, 1975);

California Air Resources Board, Air Quality - Land Use Planning Handbook for California - Part I; Planning for Air Quality, (April, 1975);

Livingston and Blaney, A Report on Guidelines for Relating Air Pollution Control to Land Use and Transportation Planning in the State of California (Sacramento: California State Air Resources Board, 1973);

Alan M. Voorhees and Associates, Guidelines to Reduce Energy Consumption Through Transportation Actions (Washington: Urban Mass Transit Administration, May, 1974);
5. San Bernardino County Environmental Improvement Agency, The Air Quality Plan of San Bernardino County, October, 1975.
6. Planning and Conservation Foundation, Land and the Environment: Planning in California Today, prepared by Sedway/Cooke, (William Kaufmann, Inc., 1975).

